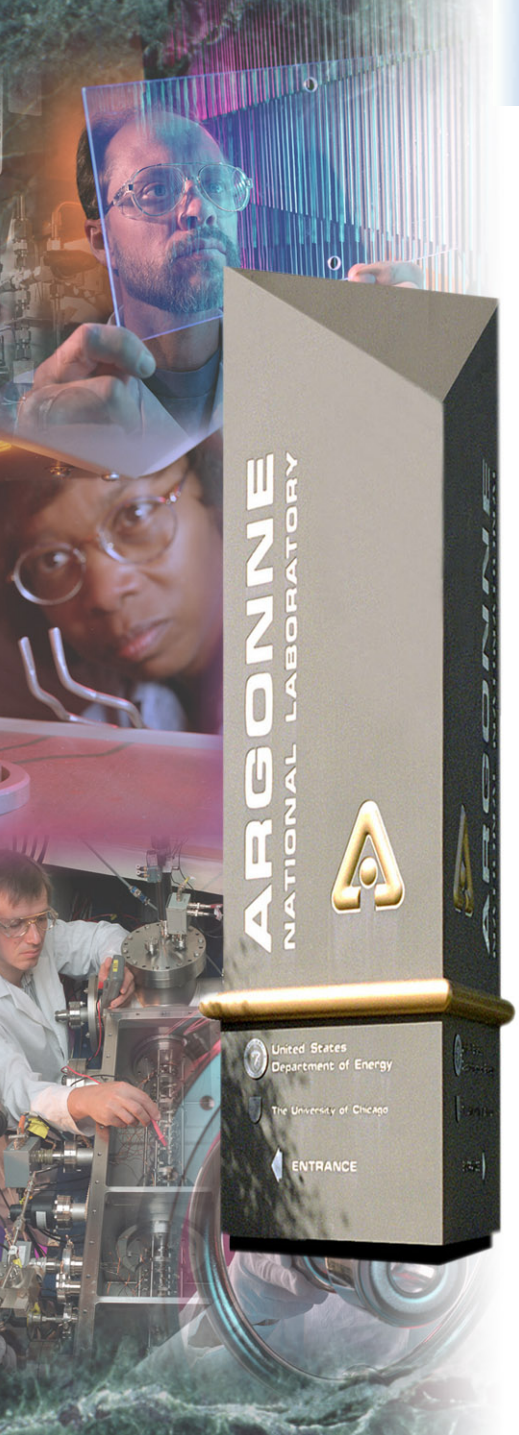



# Implications of Biobased Fuels and Chemicals for Midwest Manufacturing

*James R. Frank*
*Director, Biotechnology and Biodefense Applications*
*Argonne National Laboratory*

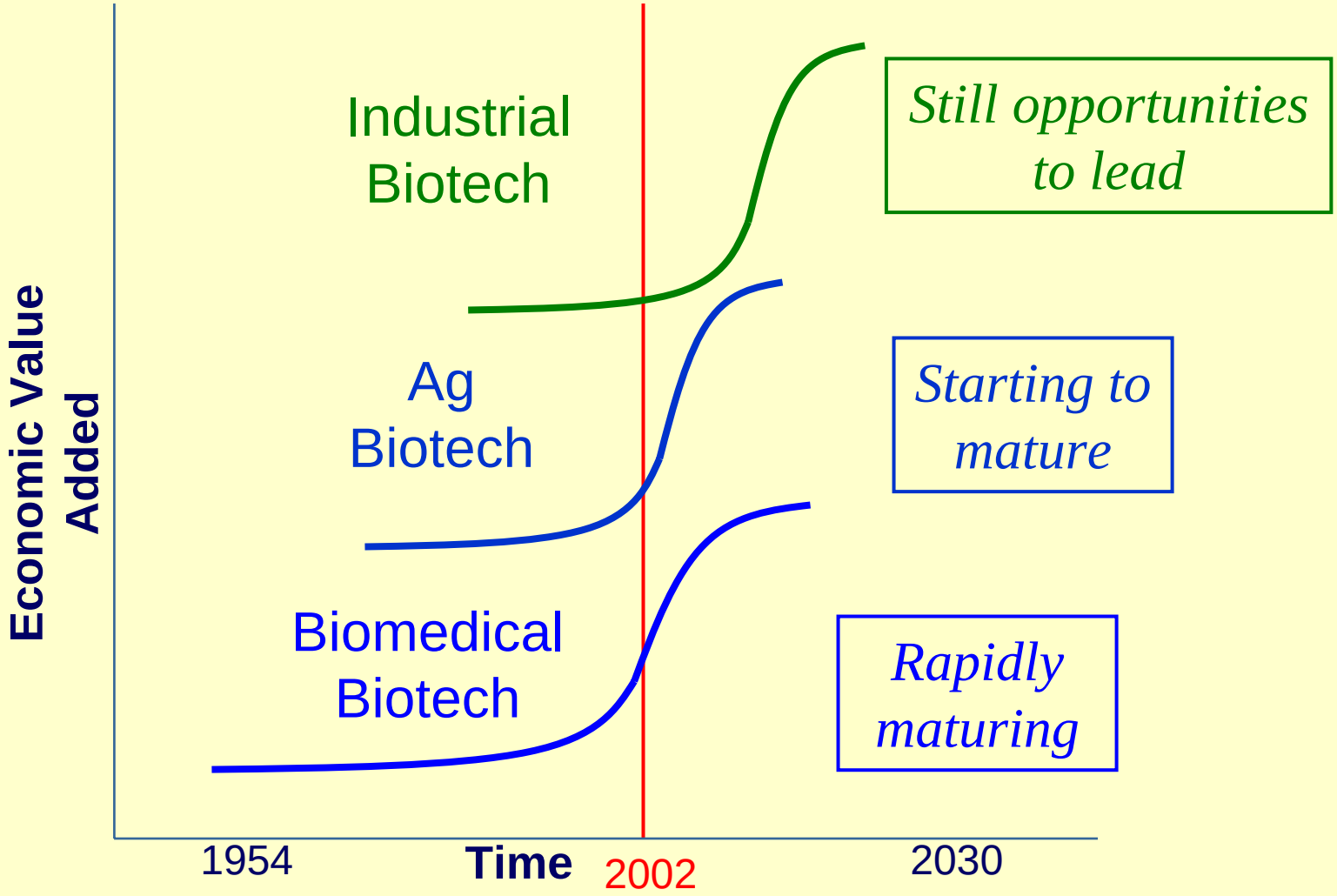
***Presented at the Wisconsin Biobased Industry Consortium***

***Madison, Wisconsin***

***October 17th, 2005***

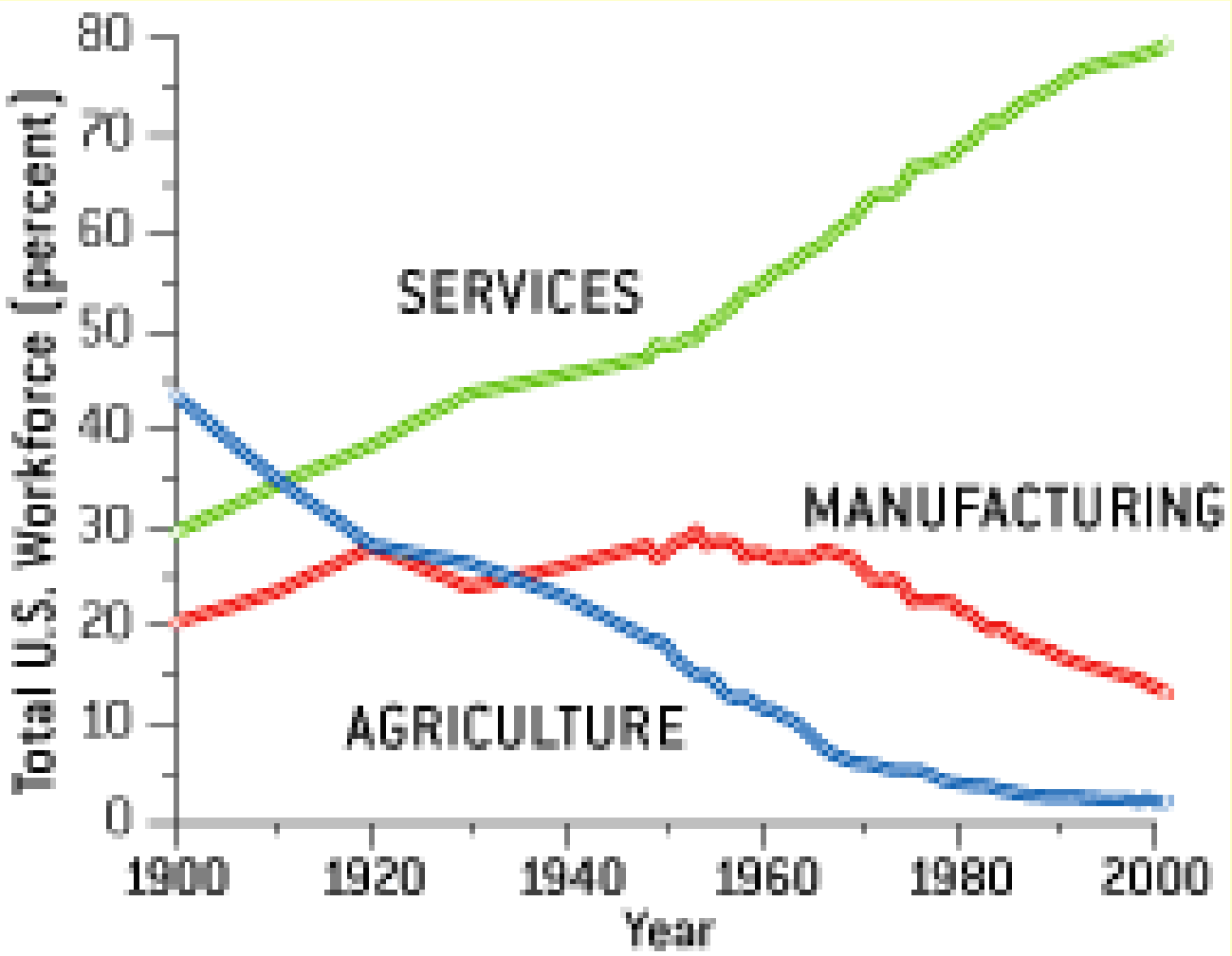
*Argonne National Laboratory is managed by The University of Chicago for the U.S. Department of Energy*

# Converging Technologies in Biotech



# Industrial (White) Biotechnology is the Third Wave

# Loss of Jobs in Manufacturing and Agriculture




*SOURCES: U.S. Bureau of the Census and U.S. Bureau of Labor Statistics*

ORNL 98-746B/abh

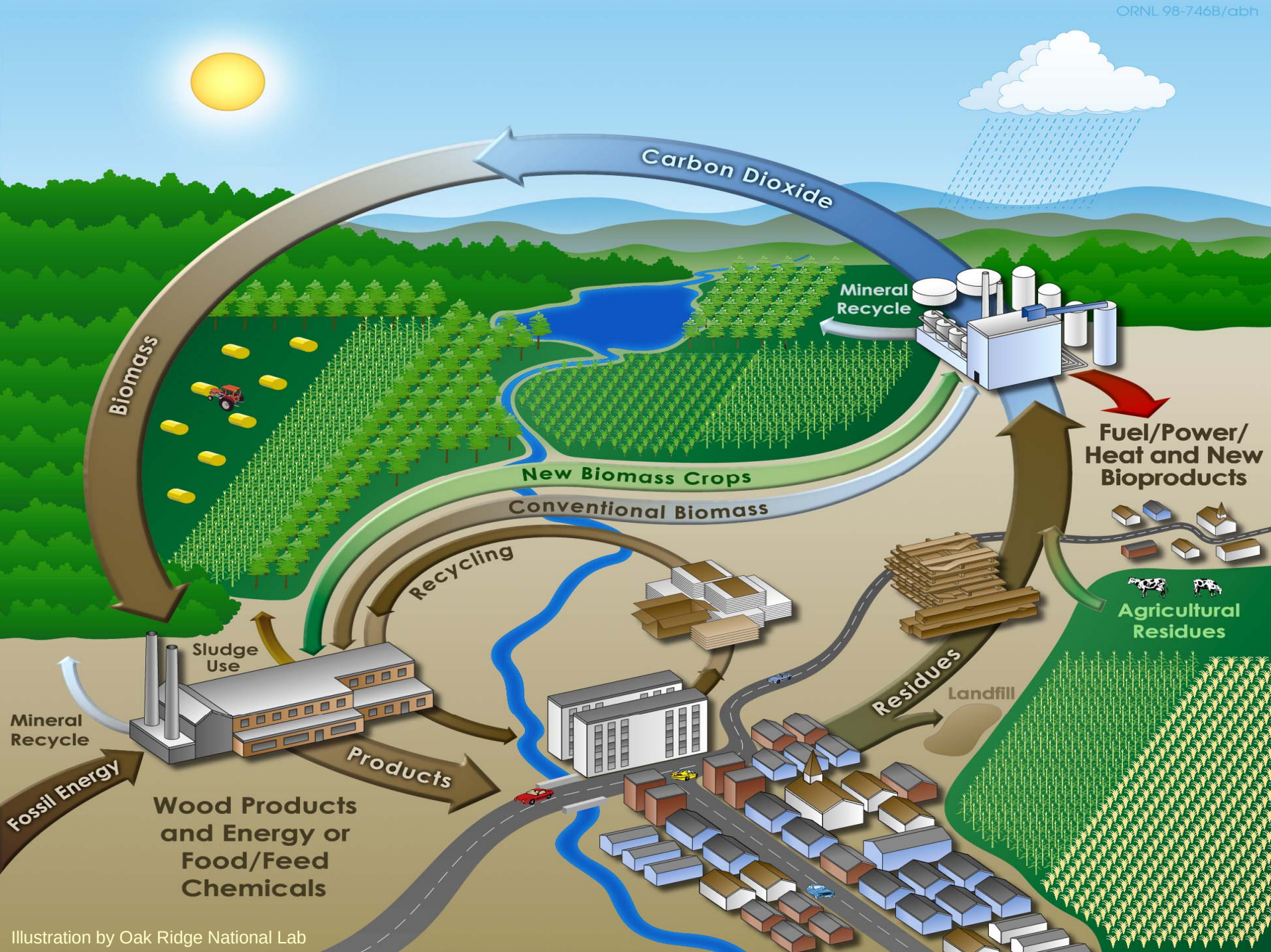
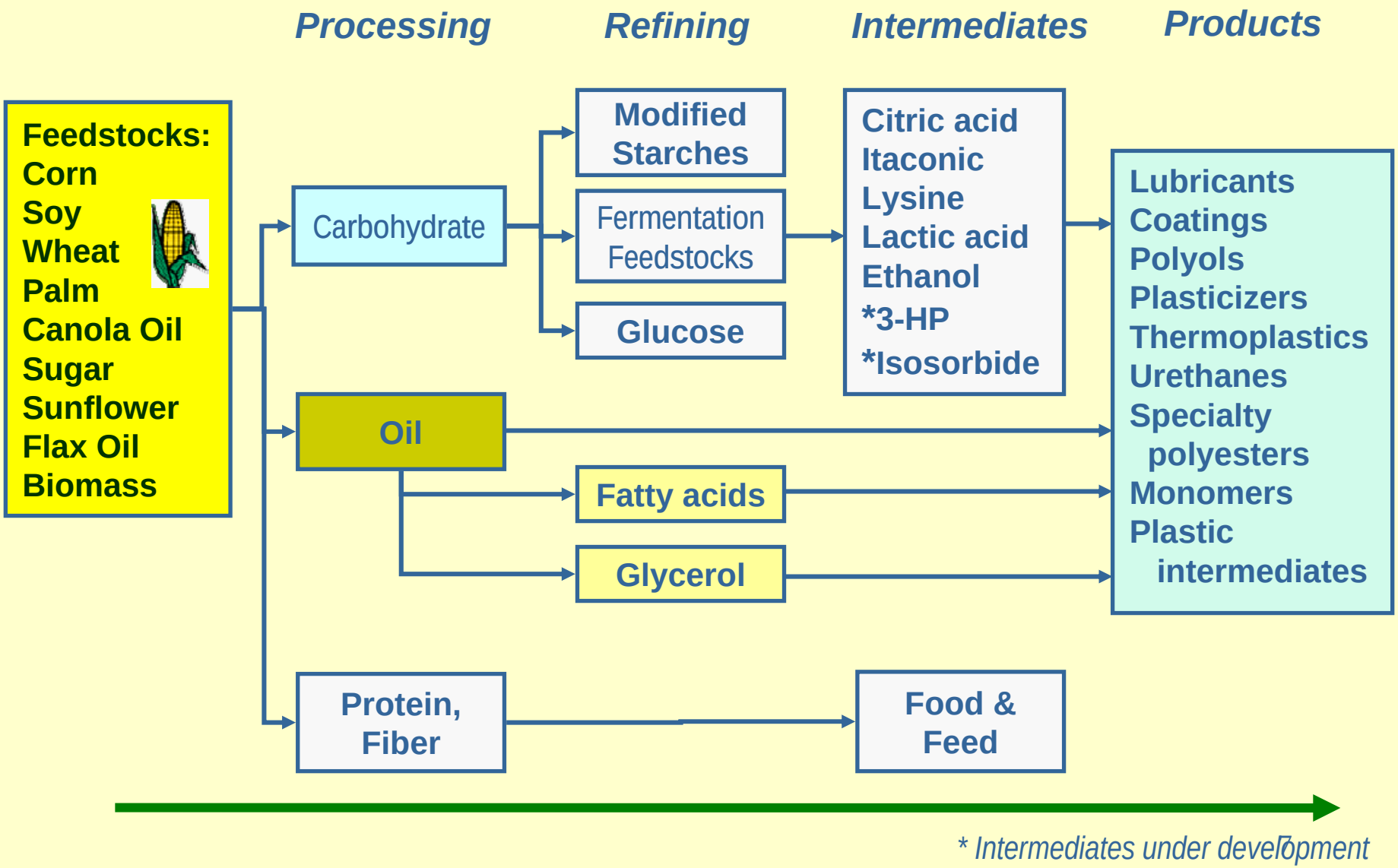



Illustration by Oak Ridge National Lab

# Biorefineries already exist in the Midwest

- They are fully integrated facilities that can process grain or biomass into a full range of commodity and consumer products

# Opportunities in Industrial Bioproducts



# Location of Bio-based Factories

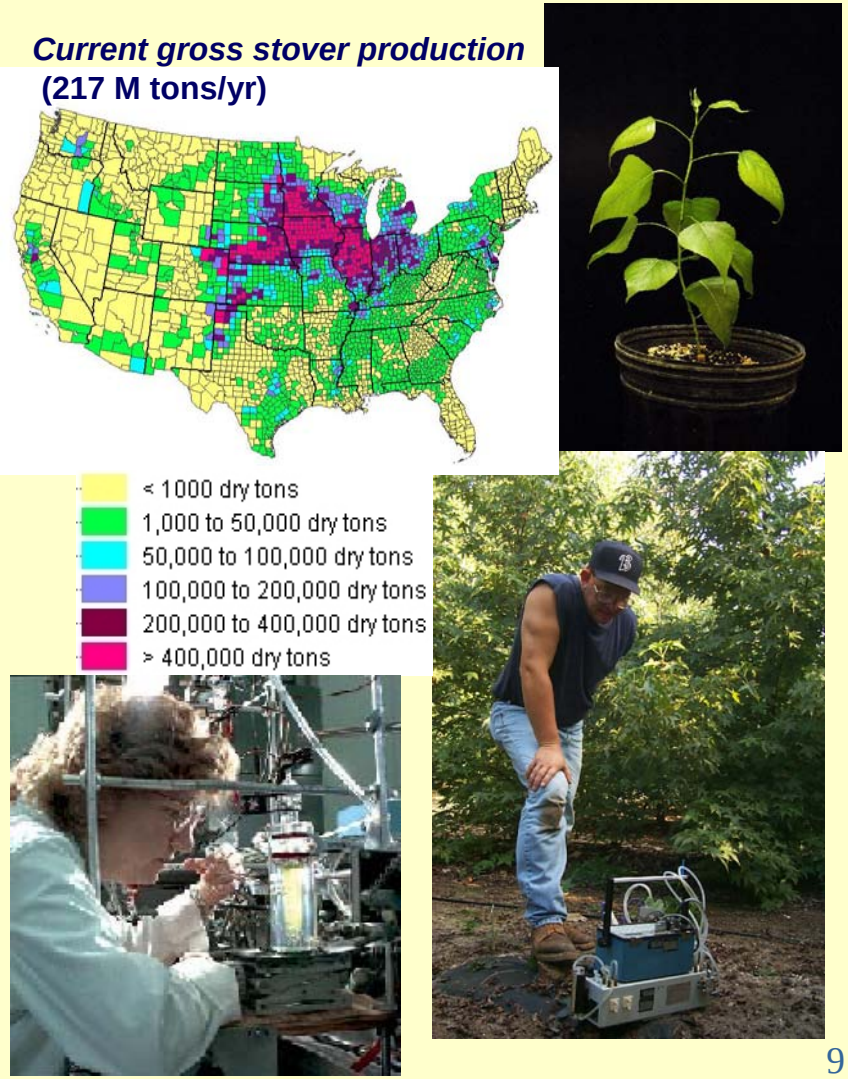

- Emerging biobased products
- Shared biobased with other products

Examples of locations of facilities manufacturing biobased products. About 150 manufacturing plants, and a single symbol often represents multiple plants.

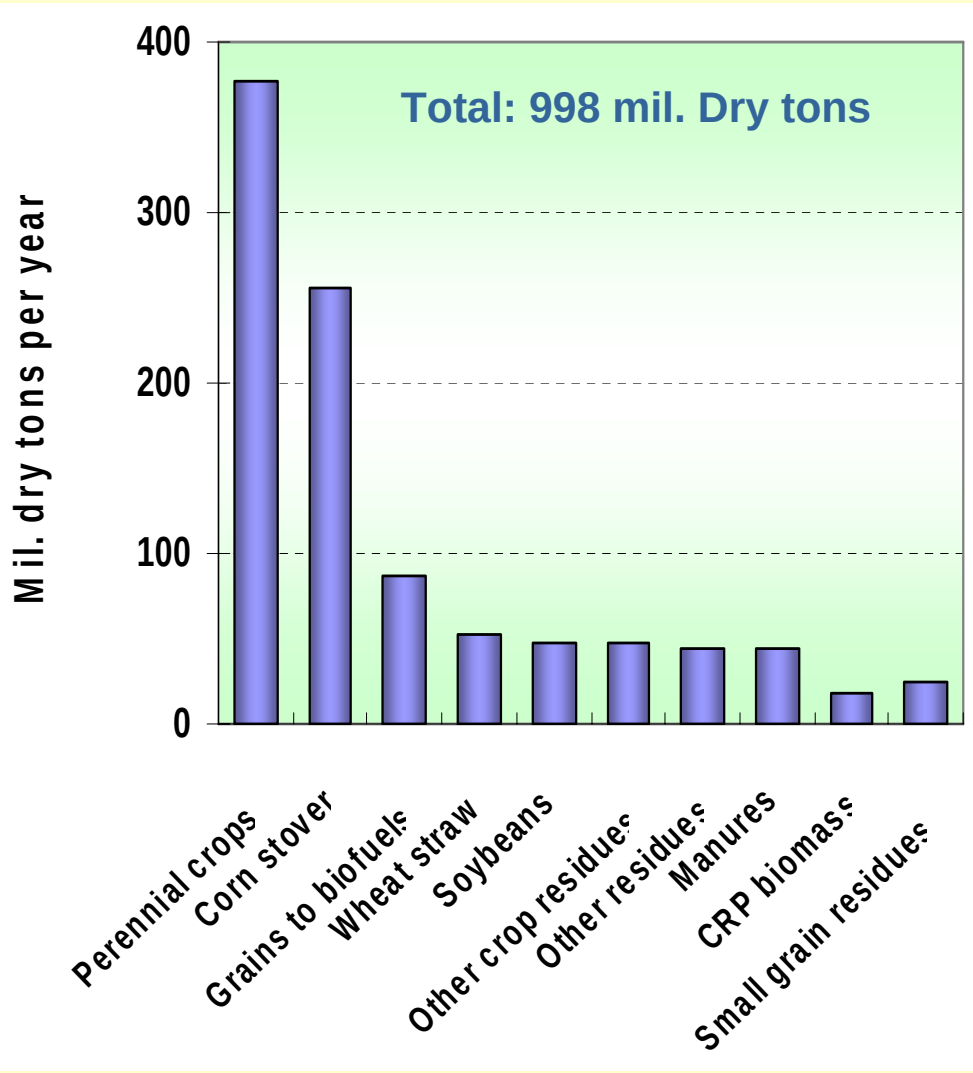
Source: http://www.bioproducts-bioenergy.gov/pdfs/strategicplan.pdf

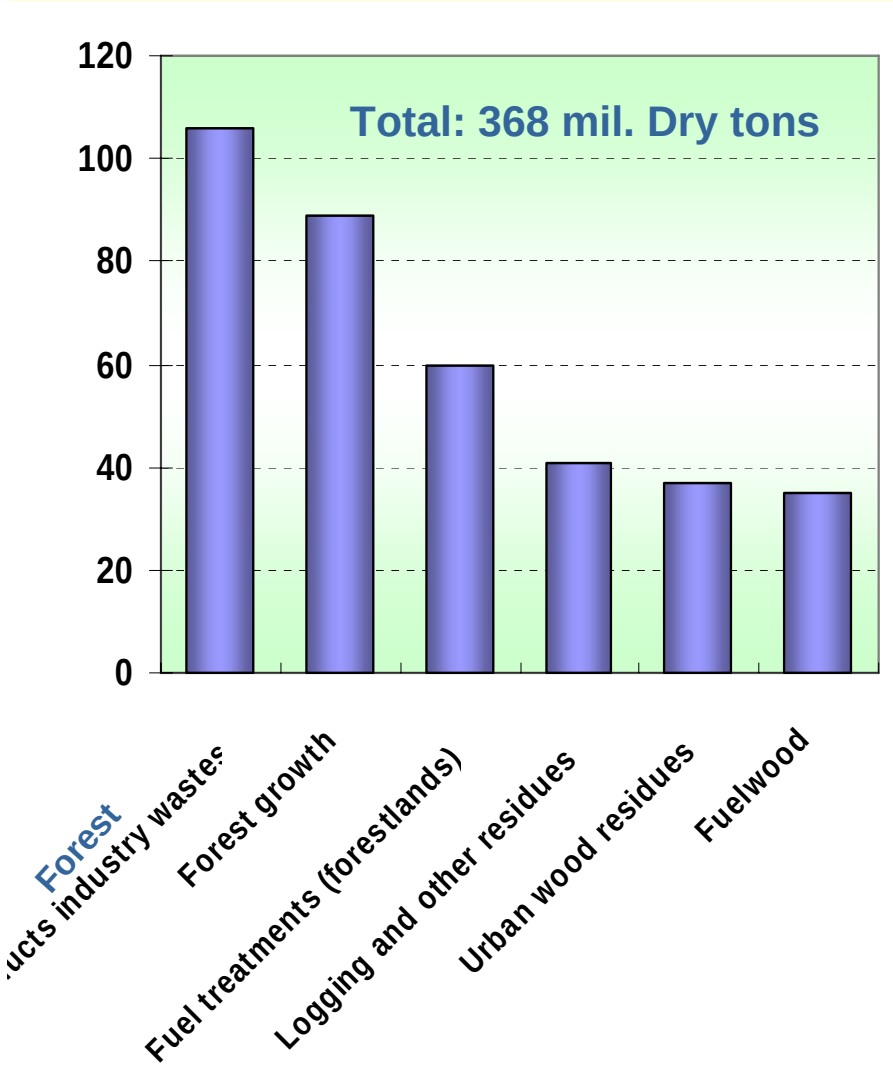
# Resource Assessment R&D at ORNL & NREL

- Feedstock Supply
  - Resource analysis, supply curves, forecasting for future scenarios
  - Advanced biomass characterization
  - Sustainability & life cycle assessment studies
  - Collection, handling, transport cost analysis
- Related Research
  - Carbon sequestration, plant/soil interactions

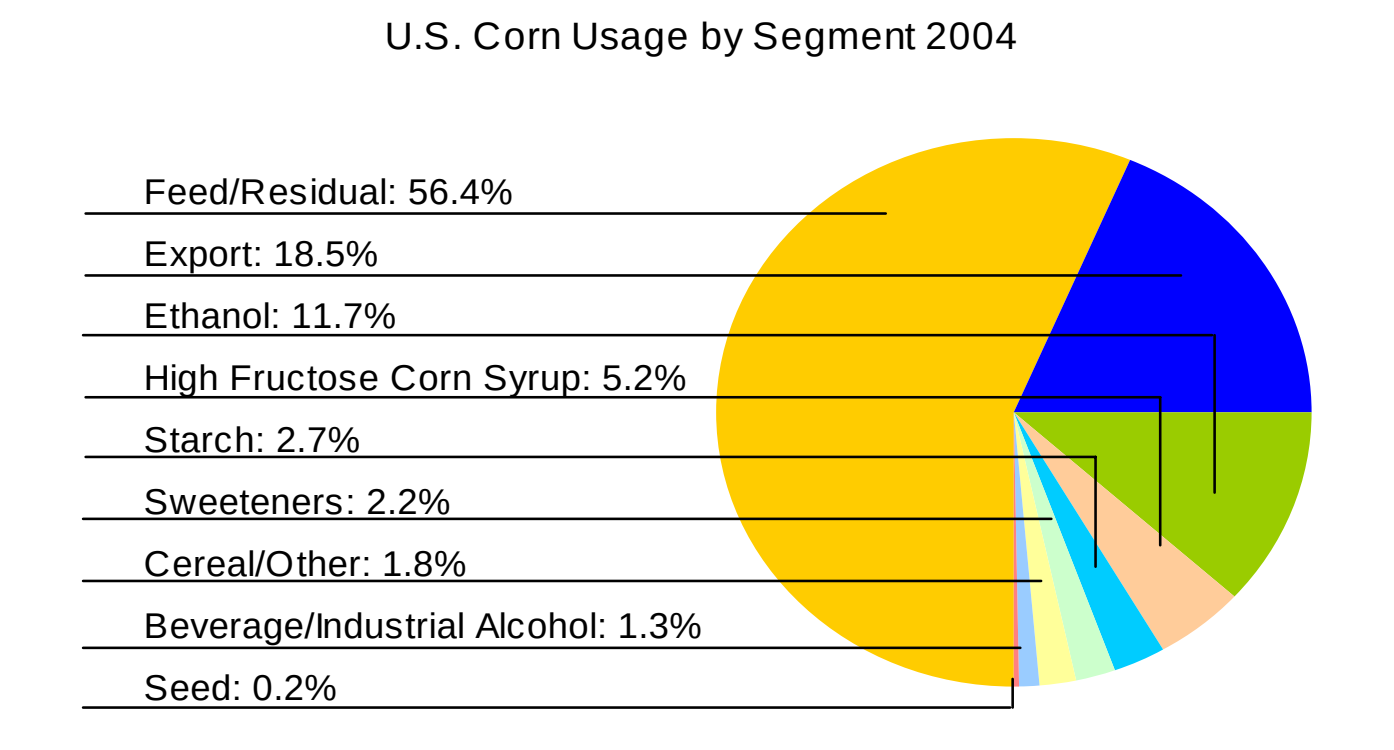


# A Recent Study by Oak Ridge National Laboratory Concludes 1.3 Billion Tons of Biomass Available in U.S. Per Year



# Of the 11.8 Billion Bushels of Corn Produced in U.S. in 2004, About 12% Was Used for Ethanol Production




- The U.S. produced 3.41 billion gallons of fuel ethanol in 2004, equivalent to 2.28 billion gallons of gasoline
- In 2003, the U.S. consumed 134 billion gallons of gasoline and 39 billion gallons of on-road diesel fuels

Source: ERS/USDA, 2004, Feed Outlook (in RFA, 2005); EIA

# Ethanol is the current "driver"

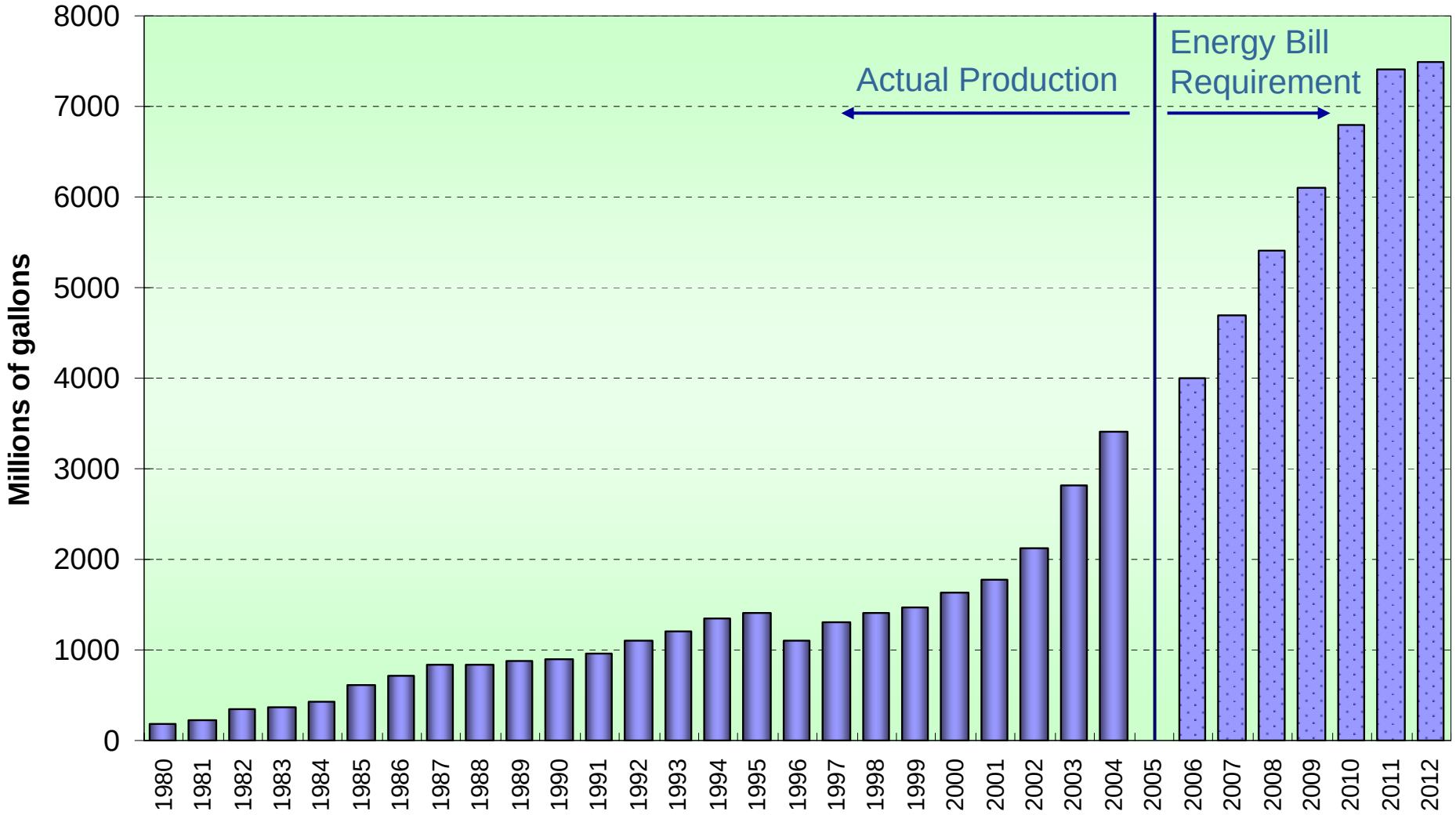
- **Ethanol can use the existing infrastructure. All autos can use 10% ethanol and some autos can use E85 which is cheaper than gasoline. Yearly increases in ethanol production about 20%**
- **U.S. requires about 10 M b/d of liquid fuel. 10% can be supplied from corn (currently at 3%), 20% if stover/ag residues are used, and 70% if energy crops (e.g. hybrid poplar, switchgrass on marginal lands) are also used.**
- **Nearly 95% of U.S. ethanol comes from corn, not lignocellulose.**
- **Currently, 83 ethanol plants (about 1/3 less than 3 years old), 25 under construction, and many more on the drawing board. Most are in the Midwest.**
- **2/3 of ethanol plants are dry mills**
  - **Avg size 30 million gallons/year vs. 100 million gallons/yr for wet mills**
  - **Reasonable size to raise capital by regional farm cooperatives, banks, and individual investors ($25K to 100K)**
- **Every state dollar used to support an ethanol facility returns $12-13 back to State economy.**

# BIOWA

**Based on a 40 million gallon per year corn to ethanol plant BIOWA estimates the following impacts on a local community:**

- **One-time boost of $142 million during construction**
- **Expand the local economic base of the community by $110.2 million/yr through the direct spending of $56 million**
- **Create 41 full-time jobs at the plant and a total of 694 jobs throughout the entire economy**
- **Increase the local price of corn by an avg 5-10 cents/bushel, adding significantly to farm income surrounding the plant**
- **Increase household income for the community by $19.6 million annually**
- **Boost state and local sales tax receipts by an avg of $1.2 million (varies depending on local rates)**
- **Provide an avg 13.3% annual return on investment over 10 years to a farmer who invests $20,000 in an ethanol production facility.**

# U.S. Fuel Ethanol Production Has Experienced Large Increases, and the Trend Will Continue



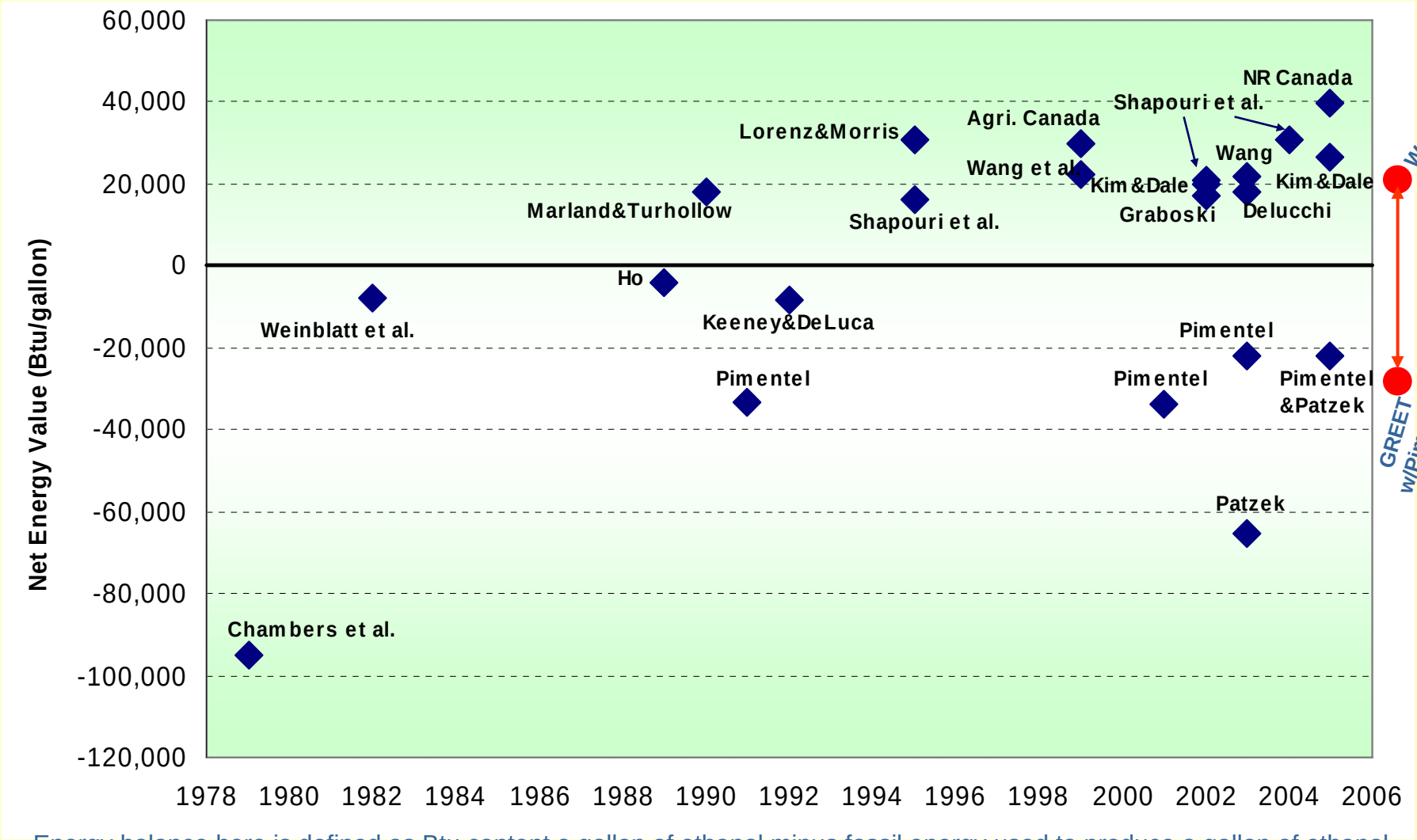

Source: Renewable Fuels Association

# The Energy Bill Encourages Production of Cellulosic Ethanol

- Creates a credit-trading program where 1 gallon of cellulosic ethanol is equal to 2.5 gallons of renewable fuel
- Creates a program for production of 250 million gallons of cellulosic ethanol in 2013
- Creates a Loan Guarantee Program of $250 million per facility
- Creates a $650 million Grant Program for cellulosic ethanol
- Creates an Advanced Biofuels Technologies Program of $550 million

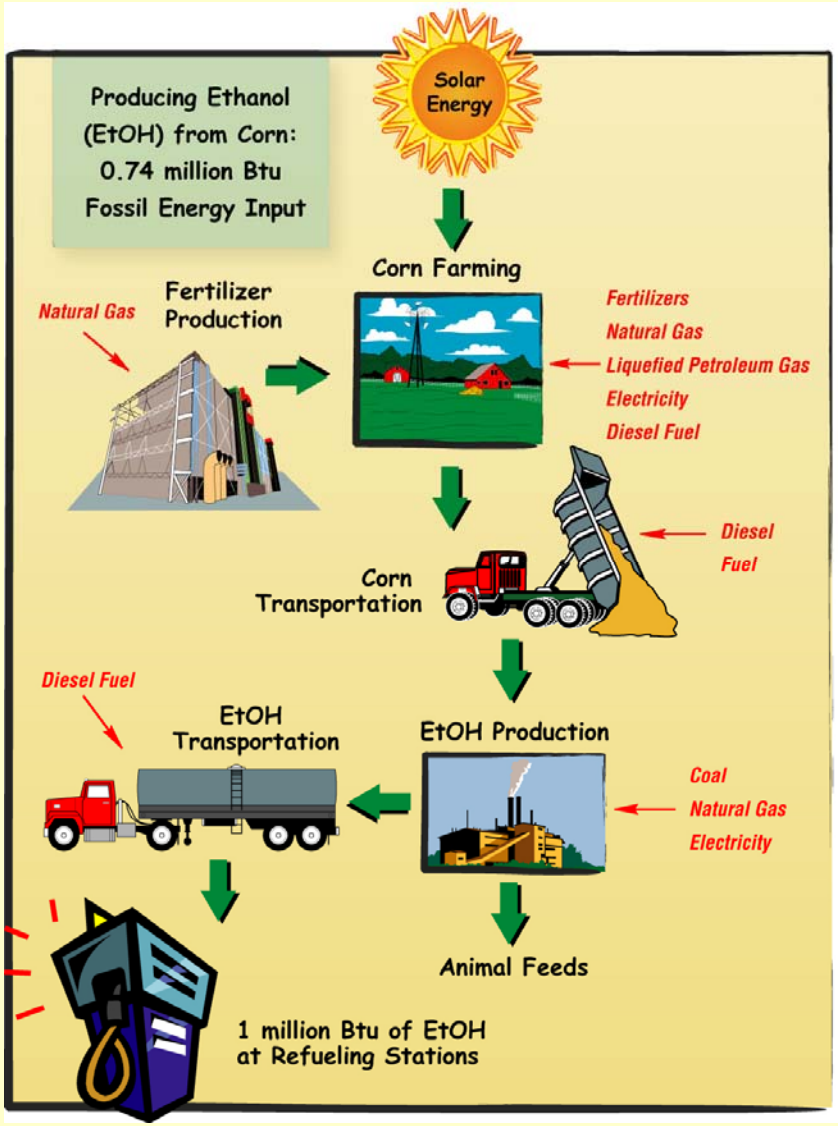
**Information is courtesy of the Renewable Fuels Association**

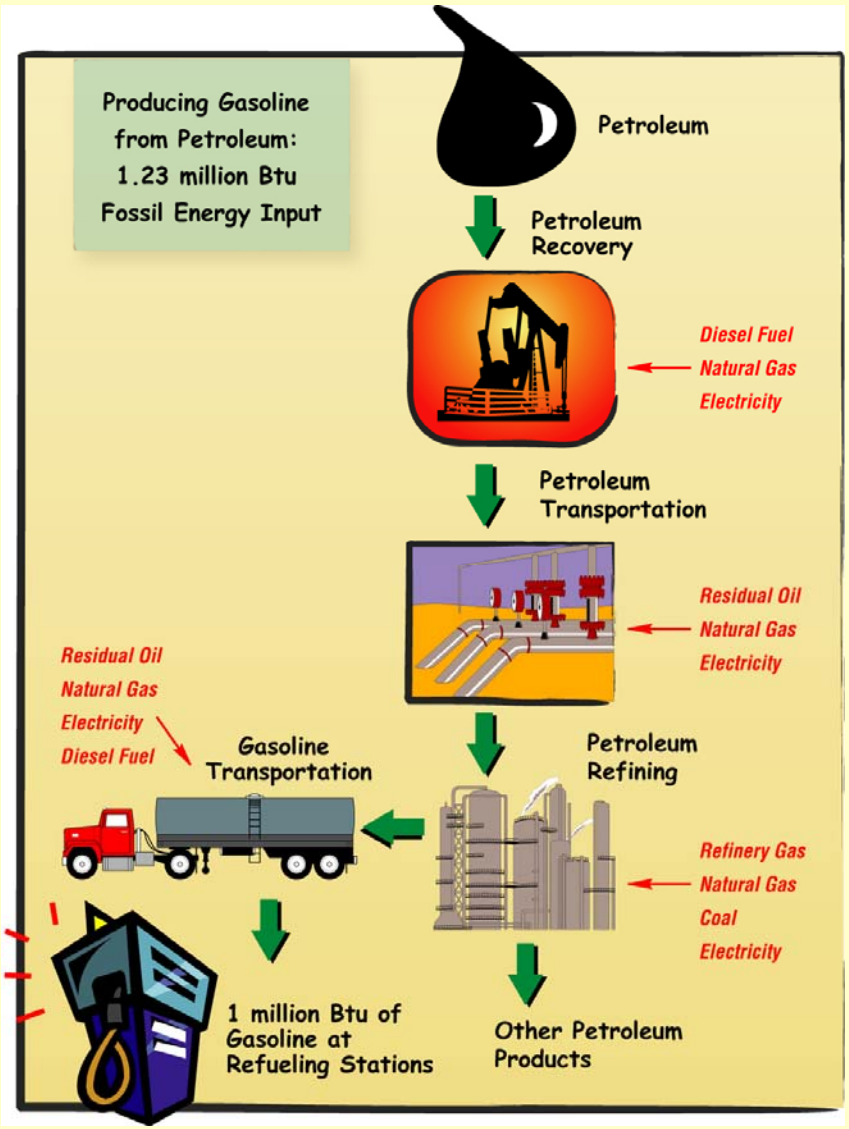
# Most of the Recent Corn EtOH Studies Show a Positive Net




Energy balance here is defined as Btu content a gallon of ethanol minus fossil energy used to produce a gallon of ethanol

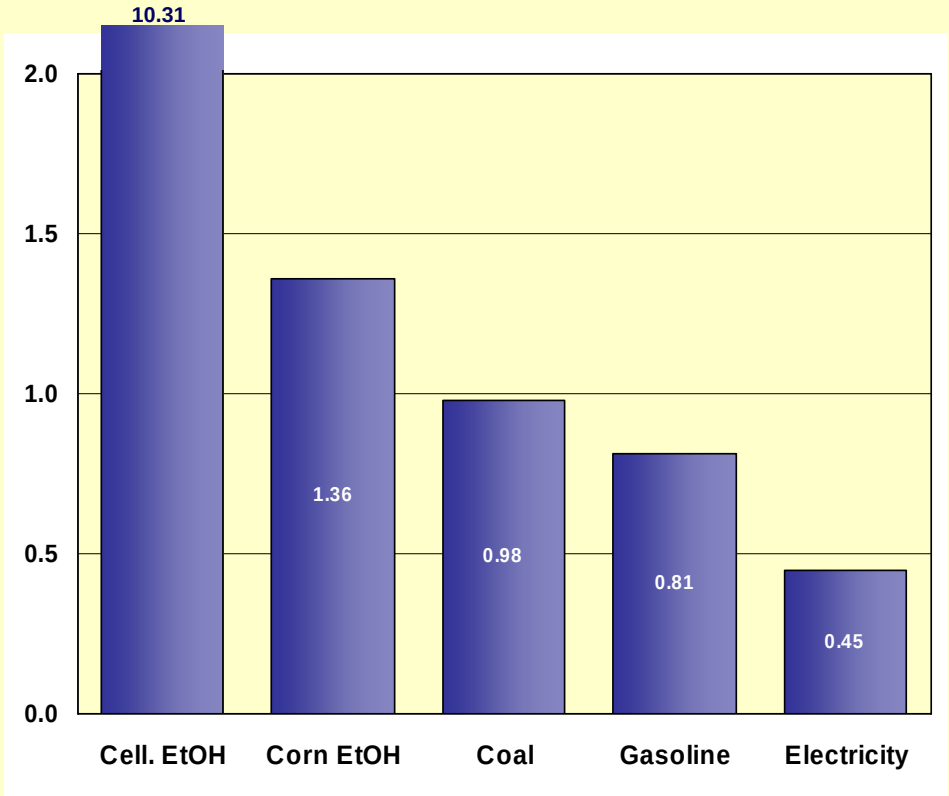
# Comparative Results Between Ethanol and Gasoline Are More Relevant to Policy Debate

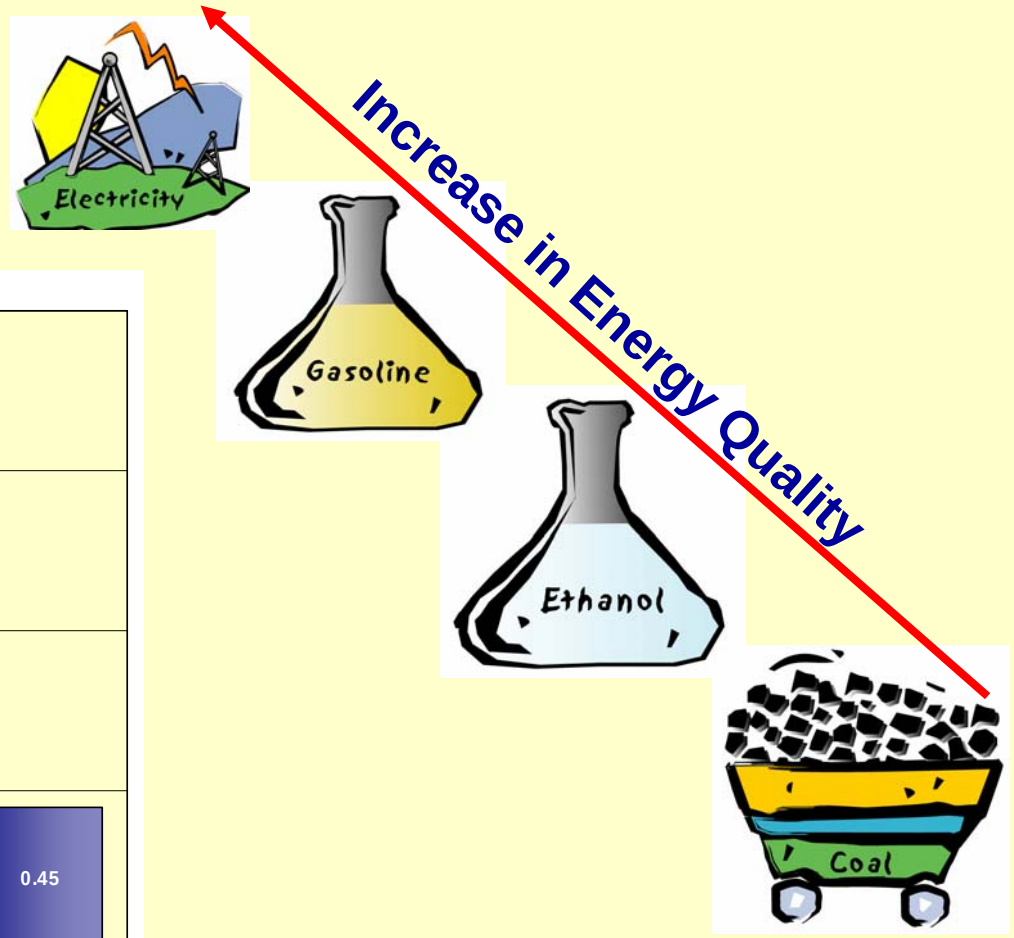


# Energy in Different Fuels Can Have Very Different Qualities

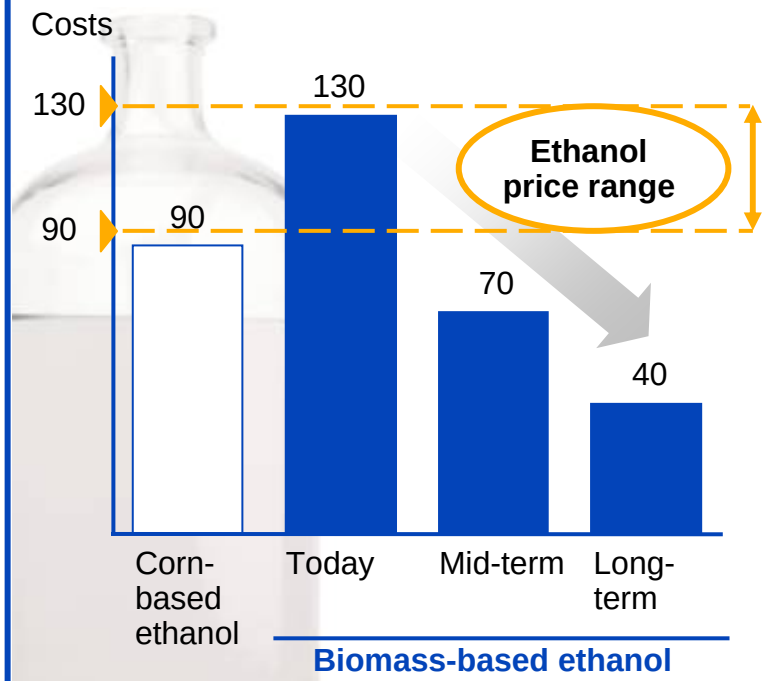
**Fossil Energy Ratio (FER) = energy in fuel/fossil energy input**



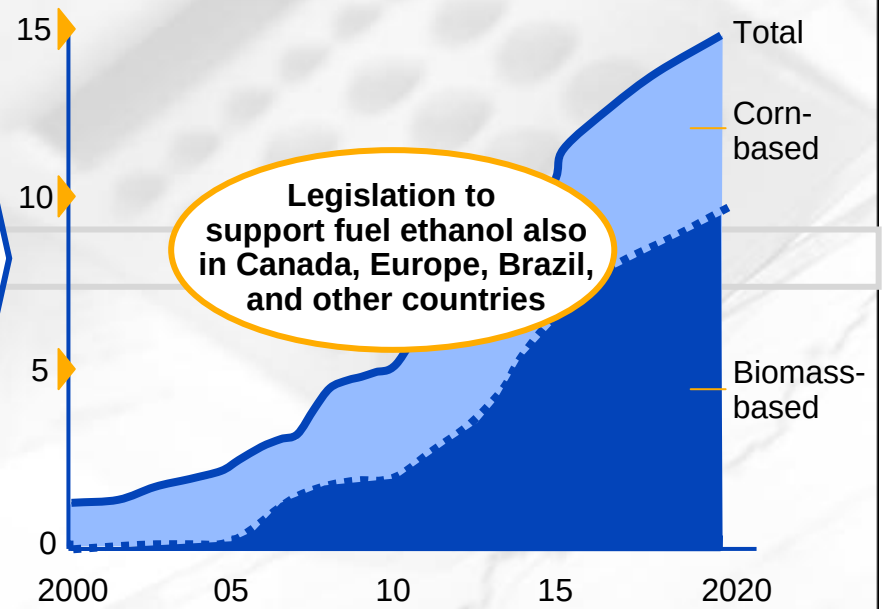



# Bio-ethanol is among the first and biggest markets to profit from low-cost biomass feedstock and it uses existing energy infrastructure

**Cost reduction**
US cent/gallon




**US market growth (DOE estimate)**
Billion gallons

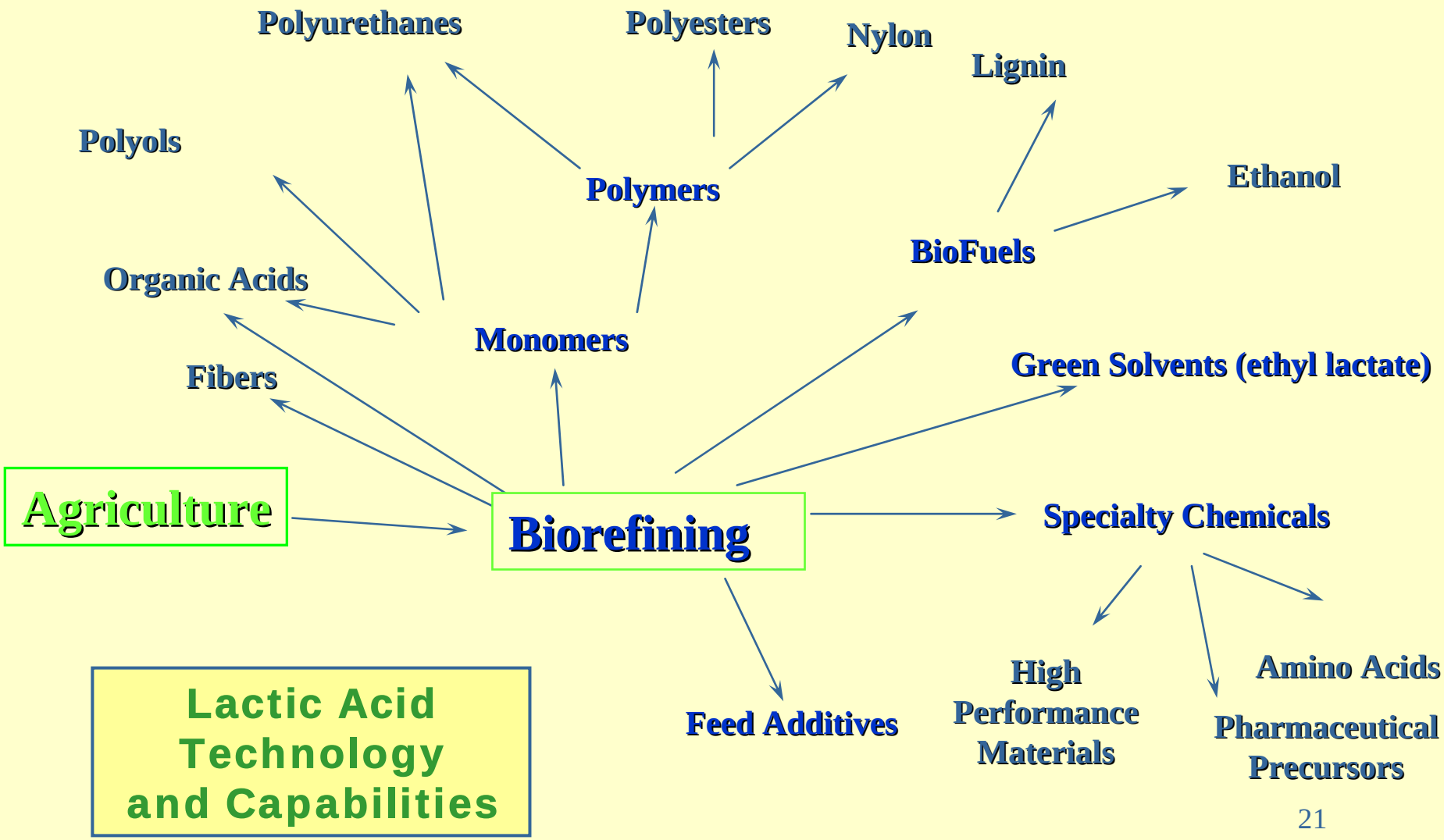



Source: US Department of Energy; GOBI International; NREL; MBI; McKinsey

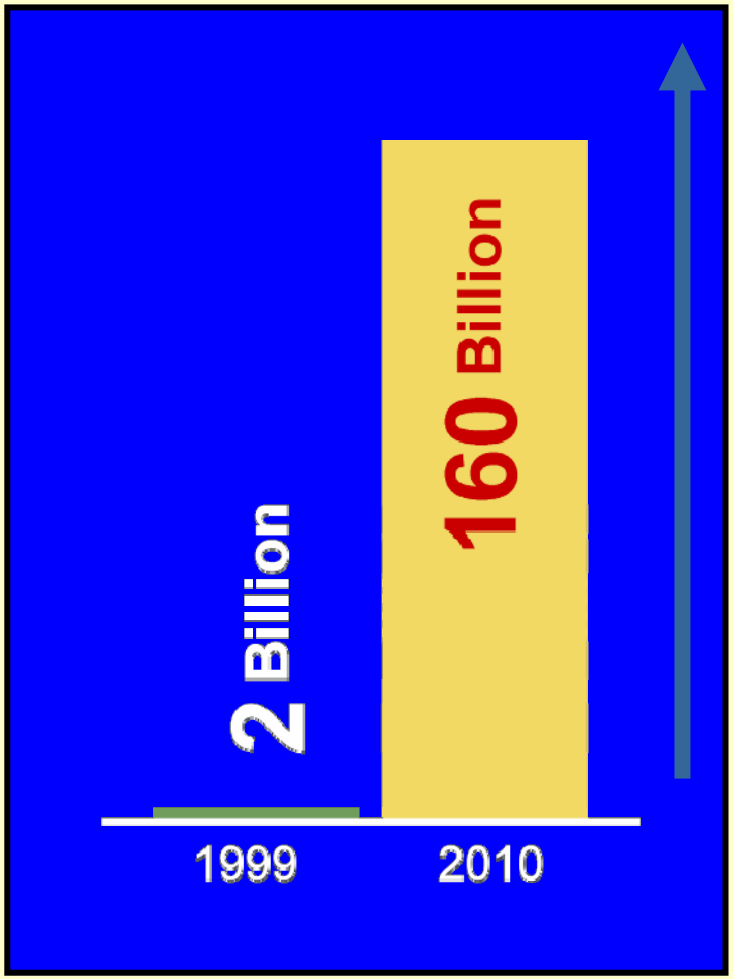
# Conclusions Related to Ethanol

- Energy balance value for a given energy product alone is not meaningful in evaluating its benefit
- Any type of fuel ethanol helps substantially reduce fossil energy and petroleum use, relative to petroleum gasoline
- Corn-based fuel ethanol achieves moderate reductions in GHG emissions
- Cellulosic ethanol can achieve much greater energy and GHG benefits

# It's Not Just About Ethanol!



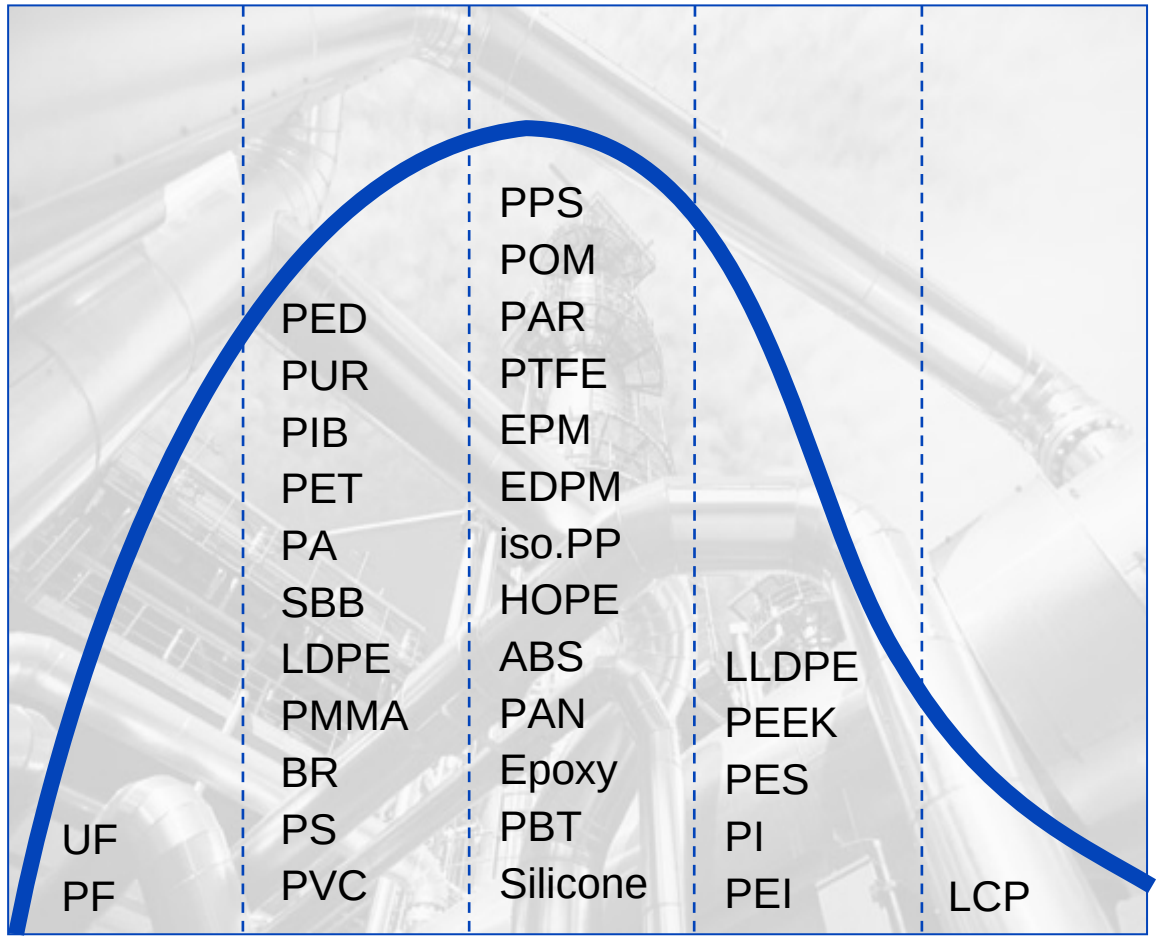
# McKinsey Industry Study: Biotech Impact on the Chemical Industry




- **Biotech will be one of key drivers of innovation and value creation over the next 10 years**
- **In 2010, about 20% of the chemical market (~USD 280 billion) will be affected by biotech with a total value creation of ~USD $160 billion**
- **Radically new business models will appear in these sectors**
  - **Ex. DuPont transforming from a chemical company to a Life Sciences company**
  - **Ethanol plants funded by local banks, farm communities, and local investors.**

# The innovation potential of fossil building blocks appears largely exploited


## Polymer innovation based on fossil building blocks




Source: McKinsey

# 5% of chemical sales depend on biotech today, but biggest products long established

| | Biotech-dependent (examples) | Sales value (USD billions) |
|---|---|---|
| **Alcohols, organic acids** | • Ethanol | 15.0 |
| | • Citric acid | 2.0 |
| **Amino acids** | • Glutamic acid | 1.5 |
| | • Lysine | 1.0 |
| **Vitamins** | • Vitamin C | 1.0 |
| | • Vitamin $B_2$ | 0.3 |
| **Pharma chemicals** | • APIs, advanced, and basic intermediates | 7.5 |
| **Specialties** | • Enzymes | 2.0 |
| | • Flavors and fragrances | 1.5 |

Source: SRI, McKinsey

# Also, existing polymers can become "bio" by using bio-based monomers or intermediates

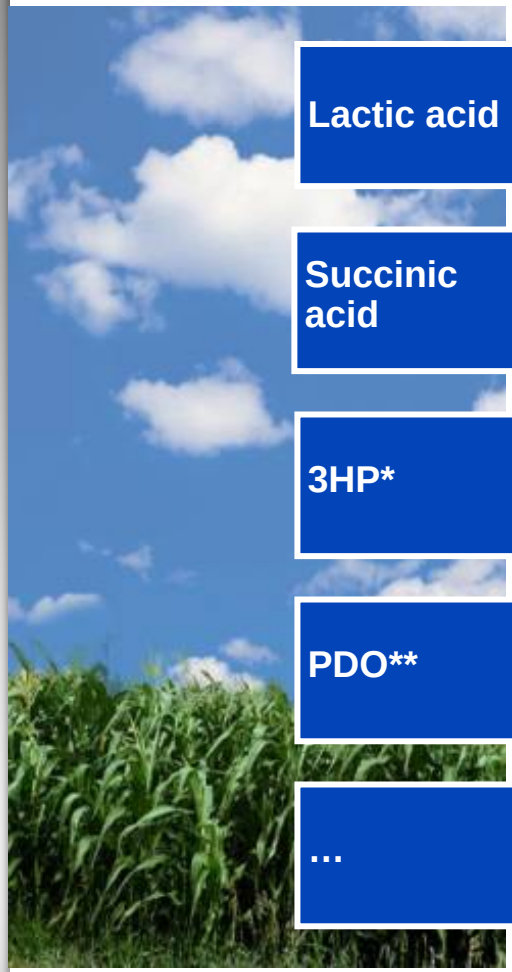
| Polymers | Sales USD billions | Biotechnology inroad |
|---|---|---|
| • Polyurethane | ~ 14.1 | • Bio-based polyols |
| • ABS* | ~ 8.0 | • Butadiene from succinic acid |
| • Acrylic fibers | ~ 4.0 | • Acrylonitrile from 3HP |
| • Nylon 6.6 | ~ 3.7 | • Adipic acid from succinic acid |
| • Unsaturated polyester resins | ~ 3.0 | • Maleic anhydride from succinic acid |
| • Polyacrylamide** | ~ 2.2 | • Acrylamide from 3HP |
| • Polybutadiene | ~ 2.2 | • Butadiene from succinic acid |
| • Nylon 6 | ~ 1.7 | • Caprolactam from fermentation |

**Technically feasible, but not cost-competitive to date**

* Acrylonitrile-butadiene-styrene resins
** Excludes superabsorbent applications
Source: SRI; CMAI; McKinsey analysis

# Innovation potential – bio-based building blocks emerge as a source of new products

**Bio-based building blocks**



- Lactic acid
- Succinic acid
- 3HP*
- PDO**
- …

- **Biopolymer (PLA)**
- Chiral drugs
- Acrylic resins
- Food additives
- Solvents
- High-performance chemicals
- Commodity chemicals

**PLA is starting to replace polyester (PET) on the basis of costs and performance**

* 3-hydroxy propionic
** Propanediol
Source: Cargill Dow; Degussa

# Chemical companies and technology players start to move against opportunities

| | Players | Activities (examples) |
|---|---|---|
| **Fine** | • DSM | • 50% of all life science chemicals sales based on biotech (USD 2 billion) |
| | • BASF | • 30% of all fine chemicals using biotech |
| | • Others | • Tripling of biologics manufacturing capacity announced |
| **Polymers** | • Cargill Dow | • PLA plant running and market being developed |
| | • Dupont | • PDO plant for Sorona biopolymer under construction |
| | • BASF | • Collaboration with Metabolix around PHAs |
| **Bulk** | • Ciba | • Introduction of enzymatic process for acrylic acid |
| | • BP | • Several research projects on fermentation routes |
| | • Shell | • Investment in Iogen for ethanol production from biomass |
| | • Cargill | • Exploring 3-HP as a new building block |
| **Specialty** | • Givaudan | • Exploitation of biotech for new flavors and aroma chemicals |
| | • Degussa | • Project houses for biocatalysis and fermentation |
| | • Novozymes | • Strong growth in enzymes |
| | • DSM | • New biotech-based food and feed specialty products |

**High level of cooperation with technology partners such as Diversa, Codexis, and Genencor as well as agriprocessors**

Source: Press clippings; McKinsey

# Chemical industry leaders put much hope on biotech

WORLD ECONOMIC FORUM

I expect most **innovation** to come from **biotechnology**

**Biotech** is the **most advanced new technology** in chemicals, nanotech might be the next

The only area of current **break-through** is **industrial biotech**

**Biotech** is a way of maintaining a **competitive edge over the Asian** competition

## Key drivers of change

- **Feedstock prices**
- **Innovation**
- Asia
- Service offerings

Source: McKinsey

# Corn: Best feedstock for Higher Value Products (Chemicals)

- Corn availability compatible with Chemical volumes

- Corn starch (sugar) can be converted to high purity products. Lignocellulosics can not (will be better for liquid fuels)

- Biobased manufacturing is scalable. Petrochemical manufacturing is not (e.g. economies of scale required)

- New technology is drastically reducing cost of biomanufacturing. Petrochemical processing is a mature industry with few new products (e.g. polymers) in the past 3 decades.

- Several new polymers under development using biobased approaches (e.g. PLA, Sorona)

# Feedstock Scenerios

Corn starch (sugar) is currently used for 95% of ethanol production but there is not sufficient corn to produce more than 10% of the liquid fuel needs of the U.S. (currently at 3% of liquid fuels)

Lignocellulosic feedstocks (Corn stover and energy crops  such as switch grass and hybrid poplar) will be lower cost than corn for fuel use (e.g. ethanol, methane, etc.) as production costs decline.  There is enough lignocellulose to produce a significant amount of the liquid fuel needs of the U.S. (potentially 70%)

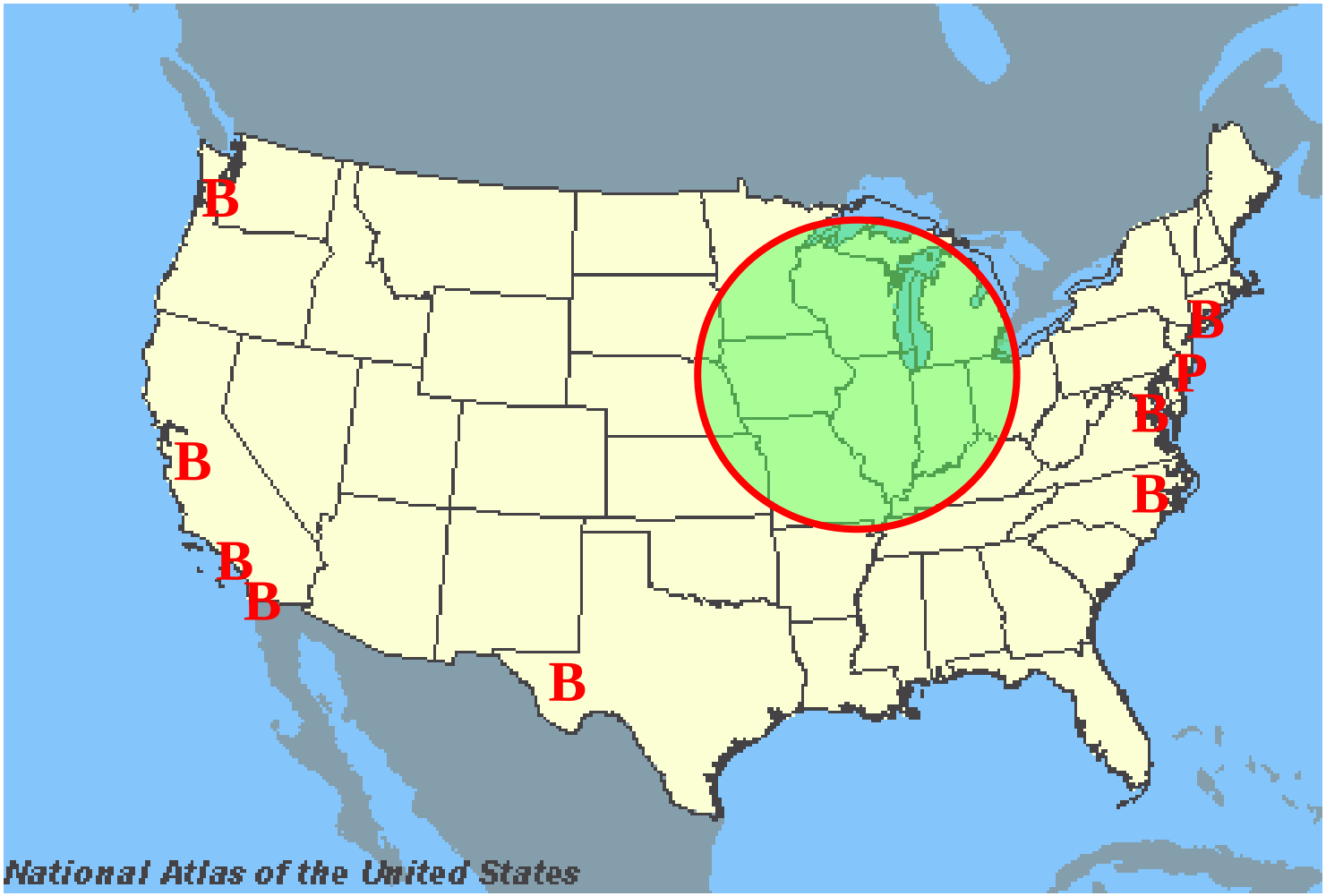
But Lignocellulosic feedstocks will not be as useful for chemicals production because they are mixed feedstocks that are more difficult to purify but can be readily used for the production of fuels

The best and most economical use of corn starch (sugar) will be for high purity chemical platform intermediates (e.g. organic acids and esters) useful for conversion into fine, bulk, and specialty chemicals and polymers.  That is also going to be the higher value use of corn and the most substantial business opportunity.

The size of the corn crop is more suitable for use as the primary feedstock for chemicals production in the U.S. based on the volume of the chemicals market (versus the much greater volume of liquid fuels required)

Therefore, corn starch (sugar) for chemicals and lignocellulose (stover or energy crops) for ethanol will eventually be the best feedstocks for biobased manufacturing in the Midwest.

## Midwest (including Chicago) should be the leaders in “Next generation manufacturing”




*New Wave Manufacturing – Scalable, uses locally available feedstocks*

# Economic Development and Infrastructure –Inexorably linked

The Midwest has:

- The feedstocks
- The technology
- The best infrastructure – roads, rail, waterways, etc.
- The chemical industry infrastructure/distribution
- Agriprocessors and integrated biorefineries
- Grass roots locally supported ethanol dry mills

The Midwest needs:

- An engaged Financial industry (including Chicago)
- A supportive Political establishment throughout the Midwest
- An Analysis (e.g. impacts of cheap sugar markets vs advantages of scalable and efficient high tech manufacturing facilities near markets, incentives required, economic and technical requirements)
- A Plan (Perhaps at the Regional/Midwest level?)

# Another Opportunity - BIO 2006 will be in Chicago

- BIO 2006 will be in Chicago April 9-12, 2006
- Sponsored by the Biotechnology Industry Organization (BIO) that represents the biotechnology industry world-wide.
- Over 20,000 participants primarily from companies, service providers, and government world-wide from the Biotechnology Industry
- We are highlighting Ag and Industrial Biotech more than any other previous meeting. Over 30 session proposals for Industrial and over 75 for Food/Ag (highest ever).
- Can be a catalyst for engaging Midwest and Chicago's financial and business communities along with other communities and efforts within the States. We also want to raise Midwest's international profile as a leader in Ag and Industrial biotech.

# Are we going to lead or follow?